An Information-Based Approach for System Autonomy Metrics
Part I: Metrics Definition

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ABSTRACT

In many real world aerospace applications, system *Autonomy* is the most single significant and meaningful attribute of an Intelligent Autonomous System - *IAS*. This paper proposes performance metrics for *IAS*, which are related to the main dimensions of *Autonomy*. Metrics are presented and defined. The metrics reflects the most meaningful characteristics of system *Autonomy*. The approach taken in this paper defines system or agent autonomy with respect to its self-capability to accomplish its assigned mission goals while operating under uncertain unexpected dynamic environment, uncertain dynamic scenario or self-faulty situations, and without or with very little intervention of a human operator or an external agent, throughout the mission cycle. The metrics enables to classify the system autonomy level, according to the sensitivity of the system performance to relative changes in autonomy related entities. The metrics are based on a comprehensive approach. It does not consider the *Autonomy* level at each phase of the sense-aware-decide-act process, separately. The proposed metrics are quantitative, relative, and based on concepts from Information theory as well as from Control and Systems theory. Using the *System Autonomy Metrics,* the system designer can compare between competitive designs, architectures, computational paradigms or, algorithms, as related to the desired system performance, with respect to *Autonomy*. These metrics are currently being used in an on-going research, development and engineering work.

KEYWORDS: *Autonomy, Autonomous Systems, Autonomy Metrics, Entropy*

1. INTRODUCTION

From an engineering point of view, performance metrics for *IAS* are needed for establishing and developing many system engineering processes or sub-processes throughout the entire multi-phase system engineering process, e.g., a) System requirements analysis; b) Preliminary design, including comparative evaluation of alternative concepts or designs; c) Concept-of-Operation development.

A fundamental question which is related to *IAS* performance metrics is: Which entity is more meaningful and practical to define and to measure with respect to *IAS* performance – *Autonomy* or *Intelligence*? Our approach is that from the user point of view, as well as from the system architect and system designer point of view, *Autonomy* is the premier characteristic attribute of an *IAS*. Although *Intelligence* enables *Autonomy*, it is not considered by us as either an appropriate or a practical system design objective or a system performance requirement *per se*. *Intelligence*, if at all can be defined, is more an internal issue.

The concept of *Autonomy* is probably more meaningful, more communicable, and more precisely quantifiable. Also, it is easier to come to a consensus about what *Autonomy* is or what an *Autonomous System* is all about, rather than what is *Intelligence* or what is an *Intelligent System*.

2. AUTONOMY

Two distinctive approaches to define system autonomy are currently being used by researchers within the *Intelligent Autonomous Systems* (including *Autonomous Agents*) research community. One approach defines autonomy as an entity which is assigned to the subject system or to the subject agent by a higher level authority, e.g., a supervisor agent or a human operator. Within the context of this approach, autonomy is defined with respect to the assigned responsibility of a system or an agent. Following this approach, autonomy reflects the agent's decision-making capability and authority, and the degree of self-control the agent has over its own decisions, see [1]. This approach is more commonly used within the *Autonomous Agents* research community. The other approach defines system or agent autonomy with respect to its self-capability to accomplish its assigned mission goals without any or with only minimal external cooperative intervention, by a remote agent e.g., a remote operator, while operating under constraints and under unstructured, unexpected, and dynamic uncertain environment as well as under evolving dynamic uncertain scenario conditions and, self-faulty situations, see [2], [3], [7], [8], [9]. We are using the later approach. Nevertheless, recent works e.g.,[7],[8],[9], proposed only qualitative metrics for system autonomy, and lacks quantitative ones. Let us define *Autonomy* and *Autonomous System.*

2.1 *Definition I*

Autonomy is an attribute of a system which characterized its self-capability to accomplish the system's assigned mission goals without any or with only minimal external cooperative intervention, by a remote agent e.g., a remote operator, while operating under constraints and under unstructured, unexpected, and dynamic uncertain environment as well as under evolving dynamic uncertain scenario conditions and, self-faulty situations.

2.2 *Definition II*

Autonomous System is a system which is self-capable of adapting its own course of action, mission plan, operation plan as well as its own dynamic behavior, in order to be able accomplish the system's assigned mission goals without any or with only minimal external cooperative intervention, by a remote agent e.g., a remote operator, while operating under constraints and under unstructured, unexpected, and dynamic uncertain environment as well as under evolving dynamic uncertain scenario conditions and, self-faulty situations.

3. CRITERIA FOR METRICS SELECTION

In the sequel, some guidelines for metrics selection are considered.

3.1 *Scope*

The proposed metrics should reflect system autonomy as perceived by an observer which is external to the system. Therefore, the autonomy should be measured outside the system boundary, i.e., within the interface of the system with external entities. Figure 1, in the sequel, illustrates the context of Autonomy Evaluation, as perceived by an external observer. Four entities are identified within the relevant context, namely: a) A Remote user or supervisor; b) An External Agent; c) Environment & Scenario; d) System Under Evaluation (SUE), which is the Autonomous Intelligent System , the autonomy of which is to be evaluated.

3.2 *Autonomy Relevance*

Meaningful, effective, and measurable metrics for system autonomy should reflect the influence of the following factors as related to system autonomy:

- Level of abstraction of the commands and the data provided to the autonomous system by a remote user/ supervisor or by an external agent.
- Information bandwidth of the data link between a remote user/supervisor or an external agent, and the system under evaluation - SUE.
- The levels of complexity, dynamics and uncertainty which are attributes to the environment under which the system is operating and executing its mission.
- The levels of complexity, dynamics and uncertainty which are attributes to the system operating scenario while executing its mission.

3.3 *Generality*

Although the meaning of performance metrics is usually domain and application specific, more general entities, such as the principle of *entropy* can be used within the framework of *IAS* performance evaluation. In our work, *entropy* is used as a general measure of entity uncertainty, and is applied to quantify various parameters. Using *entropy* as a general entity for representing uncertainty in the domains of Information, Control and System engineering was proposed by several researchers, e.g., Shannon [4], Saridis [5], and Conant [6].

3.4 *Structure Independence*

The metrics for autonomy should be independent of the internal structure, e.g. : a) type of architecture; b) number of levels of the hierarchy; c) the decomposition of *IAS* internal processes to resolution scales; d) the computational paradigms, e.g. fuzzy vs. neural networks vs. "classical" optimization techniques, and e) other internal specific features. The attempt, taken by some researchers in the field, to establish metrics which takes into account the internal specifics of the system will eventually lead to an endless confusing and unpractical effort, and to unstable solution-depended metrics. *System Autonomy* is a system attribute as perceived by an external observer. By way of analogy, consider a consumer which wants to buy a new car. His decision on which model to buy, will not depend on whether the fuel injection control system uses a fuzzy logic based controller or a differential geometry based non-linear controller. However, his decision will probably be based on user-centered parameters such as: fuel consumption (kilometers per liter), number of passengers, riding quality, safety measures, to name but a few. In such evaluation, the internal specifics are irrelevant, although they probably influence the final outcome. So are the internal specifics when one has to evaluate the performance of an *Autonomous Intelligent System*.

3.5 *Absolute vs. Relative*

The proposed metrics are all relative. We could not find any meaningful absolute metrics for autonomy. Therefore, instead of using absolute metrics to evaluate *System Autonomy*, we are using sensitivity measures [10] to evaluate *System Autonomy*.

4. METRICS

In the following section, the proposed metrics for *IAS* performance evaluation are defined. The legend used is described as follows:

4.1 *Legend*

(1)

$Legend$:

ChS - *Communication Channel Sensitivity*

EnS - *Environment Sensitivity*

InS - *Information Sensitivity*

ScS - *Scenario Sensitivity*

SsS - *Self-Status Sensitivity*

H - *Entropy*

$H(\Psi, n, R)$ - *System Entropy*

$H(\Gamma, n, R)$ - *Environment Entropy*

$H(\Lambda, n, R)$ - *Scenario Entropy*

$H(I, n, R)$ - *Information Entropy*

C - *Channel Capacity of Data Link between Remote-User or External Agent to System*

Ψ - *System Under Evaluation (SUE)*

Γ - *Environment*

Λ - *Scenario*

I - *Externally provided system Information (global and mission related)*

Θ - *Self-Status*

Φ - *Remote User*

Ω - *Problem Context*

n - *Time step index*

R - *Geographic Location*

4.2 *Entropy*

We are using *entropy* as a measure of uncertainty or 'disorder' of an entity state, e.g., a system state, an environment state, or a scenario state. The uncertainty associated with predicting the next entity state, given the current entity state, is a measure of the entity irregularity or 'disorder'. For the sake of generality, we consider both spatial and temporal dependence of the associated entities. However, for certain entities, only one independent variable is relevant. For example, terrain irregularity can be represented by spatial depended entropy, since it is a stationary entity. The less is the entity regularity, the greater is the next state prediction uncertainty and consequently, the greater is the associated entropy. Thus, entropy can be used as a measure of environment state uncertainty as well as a measure of scenario state uncertainty. Entropy can also be used as a measure of system uncertainty, which is directly related to system performance. It can represents the uncertainty in selecting the appropriate control from the set of all admissible controls [5]. Entropy can also be used for representing performance, e.g., the entropy which is associated with the system tracking error along a planned trajectory in the system state space.

Within the context of this work, we define *entropy* as follows:

(2)

Entropy Definition

$$P(\chi, n, R) = Prob\ \{\chi(n+1,\ R+\Delta R)=\chi_l \mid \chi(n,R)\}$$

$$\chi_l \in \{X\}$$

$$H(\chi,n,R) = -\sum_l P(\chi,n,R) \bullet ln\, P(\chi,n,R)$$

χ - *Entity State* - *(e.g., best control action; Environment State; Scenario State)*

$H(\chi, n, R)$ - *Entity* χ *Entropy*

$H(\Psi, n, R)$ - *System Entropy*

$H(\Gamma, n, R)$ - *Environment Entropy*

$H(\Lambda, n, R)$ - *Scenario Entropy*

$H(I, n, R)$ - *Information Entropy*

$H(\Theta,n,R)$ - *Self-Status Entropy*

4.3 *Communication Channel Sensitivity*

Communication Channel Sensitivity- ChS, is defined as the relative change of the system entropy which is caused by a relative change in the channel capacity of the communication data link between a remote-user and the System Under Evaluation - *SUE*, or between an external agent and the *SUE*. This measure is associated with the system performance dependence on a data channel between the system and an external cooperative agent, e.g., remote operator. Given a certain context, the higher is the sensitivity of the system performance to the above mentioned channel capacity, i.e., the system is depended on the capacity of the data channel to an external support provider, the lower is the level of the system autonomy.

(3)

Communication Channel Sensitivity :

$$(ChS)_n = \frac{\Delta H(\Psi,n))/H(\Psi,n)}{\Delta C(n)/C(n)}$$

$|| \ \Psi=\Psi_m;\ C=C_f;\ \Gamma=\Gamma_a;\ \Lambda=\Lambda_d;\ \Phi=\Phi_b;\ H(\Psi,n) \neq 0;\ C(n) \neq 0$

The Average Communication Channel Sensitivity is given by:

$$\overline{ChS} = \frac{1}{n} \sum_{k=1}^{n} (ChS)_n$$

$\Psi_\mu \in \{\Psi\};\ X_\phi \in \{X\};\ \Gamma_\alpha \in \{\Gamma\};$

$\Lambda_\delta \in \{\Lambda\};\ \Phi_\beta \in \{\Phi\};\ \Omega = (\Gamma, \Lambda, \Phi, I)$

Definitions:

If $\overline{ChS} \prec -1 \Rightarrow$ *SUE is Non-Autonomous w.r.t. C, under context* Ω

If $-1 \prec \overline{ChS} \prec 0 \Rightarrow$ *SUE is Partial Autonomous w.r.t. C, under context* Ω

If $\overline{ChS} \equiv 0 \Rightarrow$ *SUE is Completely Autonomous w.r.t. C , under context* Ω

If $\overline{ChS} \succ 0 \Rightarrow$ *SUE is Non-Supervisable w.r.t. C, under context* Ω

4.4 *Environment Sensitivity*

Environment Sensitivity- EnS, is defined as the relative change of the system entropy which is caused by a relative change in the environment entropy, or uncertainty. This measure is associated with the system performance dependence on the uncertainty imposed by the continuous interaction of the autonomous system with its surrounding environment, and it reflects the self-capability of the system to function autonomously in uncertain unexpected

(4)

Environment Sensitivity :

$$(EnS)_{n,R} = \frac{\Delta H(\Psi,n)/H(\Psi,n)}{\Delta H(\Gamma,n,R)/H(\Gamma,n,R)}$$

$|| \ \Psi=\Psi_m;\ C=C_f;\Gamma=\Gamma_a;\ \Lambda=\Lambda_d;\ \Phi=\Phi_b;\ H(\Psi,n) \neq 0;\ H(\Gamma,n.$

The Average Environment Sensitivity is given by:

$$\overline{EnS} = \frac{1}{n} \sum_{k=1}^{n} (EnS)_{n,R}$$

$\Psi_m \in \{\Psi\};\ Cf \in \{C\};\ \Gamma_a \in \{\Gamma\};$

$\Lambda_d \in \{\Lambda\};\ \Phi_b \in \{\Phi\};\ \Omega = (\Lambda, \Phi, C, I)$

Definitions:

If $\overline{EnS} \succ 1 \Rightarrow$ *SUE is Non-Autonomous w.r.t.* Γ, *under context* Ω

If $0 \prec \overline{EnS} \leq 1 \Rightarrow$ *SUE is Partial Autonomous w.r.t.* I *under context* Ω

If $\overline{EnS} \equiv 0 \Rightarrow$ *SUE is Completely Autonomous w.r.t.* Γ, *under context* Ω

environment. Given a certain context, the higher is the sensitivity of the system performance to the environment uncertainty, the lower is the level of the system autonomy. An appropriate measure for the uncertainty and "disorder" of the unstructured and even dynamic environment is represented by the environment entropy.

4.5 *Scenario Sensitivity*

Scenario Sensitivity- ScS, is defined as the relative change of the system entropy which is caused by a relative change in the scenario entropy, or uncertainty. This measure is associated with the system capability to accommodate the uncertainty imposed by the scenario. Given a certain context, the higher is the sensitivity of the system performance to the evolving scenario uncertainty, the lower is the level of the system autonomy. An appropriate measure for scenario uncertainty and "disorder" is represented by the scenario entropy. The scenario uncertainty is partly contributed by the adversary unexpected and unknown reaction.

(5)

Scenario Sensitivity :

$$(ScS)_{n,R} = \frac{\Delta H(\Psi,n)/H(\Psi,n)}{\Delta H(\Lambda,n,R)/H(\Lambda,n,R)}$$

$|| \ \Psi=\Psi_m;\ C=C_f;\Gamma=\Gamma_a;\ \Lambda=\Lambda_d;\ \Phi=\Phi_b;$

$H(\Psi,n) \neq 0;\ H(\Lambda,n,R) \neq 0$

The Average Scenario Sensitivity is given by:

$$\overline{ScS} = \frac{1}{n} \sum_{k=1}^{n} (ScS)_{n,R}$$

$\Psi_m \in \{\Psi\};\ Cf \in \{C\};\ \Gamma_a \in \{\Gamma\};$

$\Lambda_d \in \{\Lambda\};\ \Phi_b \in \{\Phi\};\ \Omega = (\Gamma, \Phi, C, I)$

Definitions:

If $\overline{ScS} \succ 1 \Rightarrow$ *SUE is Non-Autonomous w.r.t.* Λ, *under context* Ω

If $0 \prec \overline{ScS} \leq 1 \Rightarrow$ *SUE is Partly Autonomous w.r.t.* Λ, *under context* Ω

If $\overline{ScS} \equiv 0 \Rightarrow$ *SUE is Completely Autonomous w.r.t.* Λ, *under context* Ω

4.6 *Information Sensitivity*

Information Sensitivity- InS, is defined as the relative change of the system entropy which is caused by a relative change in the information entropy of the system's global and mission related externally provided information, either during the pre-mission preparations, or on-the-move, via data uplink. This externally provided information includes the Mission Plan and the related Data Bases which are provided to the autonomous system externally, either by a remote user/ supervisor or by an external agent. This measure is associated with the system capability to accommodate the uncertainty of the externally provided information, and to keep functioning under such circumstances. Given a certain context, the higher is the sensitivity of the system performance to the information uncertainty, the lower is the level of autonomy. An appropriate measure for information uncertainty and "disorder" is represented by the information entropy.

(6)

Information Sensitivity :

$$(InS)_{n,R} = \frac{\Delta H(\Psi,\mathrm{n})/H(\Psi,\mathrm{n})}{\Delta H(\mathrm{I},\mathrm{n},\mathrm{R})/H(\mathrm{I},\mathrm{n},\mathrm{R})}$$

$$\|\ \Psi=\Psi_m;\ C=C_f;\ \Gamma=\Gamma_a;\ \Lambda=\Lambda_d;\ \Phi=\Phi_b;\ H(\Psi,\mathrm{n}) \neq 0;\ H(\mathrm{I},\mathrm{n},\mathrm{R}) \neq 0$$

The Average Information Sensitivity is given by:

$$\overline{InS} = \frac{1}{\mathrm{n}} \sum_{\mathrm{k}=1}^{\mathrm{n}} (\mathrm{InS})_{\mathrm{n,R}}$$

$$\Psi_\mu \in \{\Psi\};\ \mathrm{X}_\phi \in \{\mathrm{X}\};\ \Gamma_\alpha \in \{\Gamma\};$$

$$\Lambda_\delta \in \{\Lambda\};\ \Phi_\beta \in \{\Phi\};\ \Omega = (\Gamma,\ \Lambda,\ \Phi, \mathrm{C})$$

Definitions:

$$\text{If } \overline{InS} \succ 1 \Rightarrow SUE \text{ is Non-Autonomous w.r.t. } \mathrm{I}, \text{ under context } \Omega$$

$$\text{If } 0 \prec \overline{InS} \leq 1 \Rightarrow SUE \text{ is Partly Autonomous w.r.t. } \mathrm{I}, \text{ under context } \Omega$$

$$\text{If } \overline{InS} \equiv 0 \Rightarrow SUE \text{ is Completely Autonomous w.r.t. } \mathrm{I}, \text{ under context } \Omega$$

4.7 *Self-Status Sensitivity*

Self-Status Sensitivity- SsS, is defined as the relative change of the system entropy which is caused by a relative change in the system's Self-Status entropy. This measure is associated with the system capability to accommodate the uncertainty of the Self-Status of the internal sub-systems, and to keep functioning under such circumstances. Given a certain context, the higher is the sensitivity of the system performance to the Self-Status uncertainty, the lower is the level of autonomy. An appropriate measure for Self-Status uncertainty and "disorder" is represented by the Self-Status entropy.

(7)

Self-Status Sensitivity :

$$(SsS)_{n,R} = \frac{\Delta H(\Psi,\mathrm{n})/H(\Psi,\mathrm{n})}{\Delta H(\Theta,\mathrm{n},\mathrm{R})/H(\Theta,\mathrm{n},\mathrm{R})}$$

$$\|\ \Psi=\Psi_m;\ C=C_f;\ \Gamma=\Gamma_a;\ \Lambda=\Lambda_d;\ \Phi=\Phi_b;\ H(\Psi,\mathrm{n}) \neq 0;\ H(\mathrm{I},\mathrm{n},\mathrm{R}) \neq 0$$

The Average Self-Status Sensitivity is given by:

$$\overline{SsS} = \frac{1}{\mathrm{n}} \sum_{\mathrm{k}=1}^{\mathrm{n}} (\mathrm{SsS})_{\mathrm{n,R}}$$

$$\Psi_\mu \in \{\Psi\};\ \mathrm{X}_\phi \in \{\mathrm{X}\};\ \Gamma_\alpha \in \{\Gamma\};$$

$$\Lambda_\delta \in \{\Lambda\};\ \Phi_\beta \in \{\Phi\};\ \Omega = (\Gamma,\ \Lambda,\ \Phi, \mathrm{C})$$

Definitions:

$$\text{If } \overline{SsS} \succ 1 \Rightarrow SUE \text{ is Non-Autonomous w.r.t. } \Theta, \text{ under context } \Omega$$

$$\text{If } 0 \prec \overline{SsS} \leq 1 \Rightarrow SUE \text{ is Partly Autonomous w.r.t. } \Theta, \text{ under context } \Omega$$

$$\text{If } \overline{SsS} \equiv 0 \Rightarrow SUE \text{ is Completely Autonomous w.r.t. } \Theta, \text{ under context } \Omega$$

4.8 *Autonomy Sensitivity Vector – ASV*

The Autonomy Sensitivity Vector – ASV, is a 1x N vector, the components of which are the individual sensitivity functions. Using the ASV, one can classify an autonomous system into one of the following categories, under the relevant context: a) Non-Autonomous; b) Partial Autonomous; c) Completely Autonomous. Moreover, having the estimated values of ASV components, one can estimate the relative change of the system entropy, given the relative change of: a) Communication Channel Capacity; b) Environment Entropy; c) Scenario Entropy; d) Information Entropy; e) Self-Status Entropy.

(8)

$$\begin{array}{l}
\text{The Autonomy Sensitivity Vector is defined by :}\\
\text{ASV} = (\ \overline{ChS},\ \overline{EnS},\ \overline{ScS},\overline{InS},\ \ \overline{SsS}\ \ )^T\\
\text{Definitions :}\\
\text{If}\ \ \|\text{ASV}\|\ \equiv\ O,\ \Rightarrow\ SUE\ is\\
Completely\ Autonomous\ under\ context\ \Omega\\
If\ \ 0\ \prec\ \|\text{ASV}\|\ \prec 1,\ \Rightarrow\ \ \ SUE\ is\\
Partial\ Autonomous\ under\ context\ \Omega\\
\text{If}\ \ \|\text{ASV}\|\ \geq\ 1,\ \Rightarrow\ SUE\ is\\
Non\ Autonomous\ under\ context\ \Omega
\end{array}$$

5. SUMMARY

Metrics for system autonomy has been defined and presented. Following the metrics, a specific measure for a certain application can be derived directly. Associated with each definition, the broad classification of the SUE was defined. The proposed metrics are quantitative, relative and general. Using the *System Autonomy Metrics,* the system designer can compare between competitive designs, architectures or, computational paradigms, as related to the desired system performance, with respect to *Autonomy*. These metrics are currently being used in an on-going research, development and engineering work. Part II of this paper will describe some practical examples of using the proposed metrics.

REFERENCES

[1] Barber, K.S., (1999), "Agent Autonomy: Specification, Measurement, and Dynamic Adjustment", 1999, pp. 1-8.

[2] Yavnai, A., (1989), "Criteria of System Autonomability", Proc. Intl' 2nd Conference on Intelligence Autonomous Systems, Amsterdam, Dec. 1989, pp. 448-458.

[3] Yavnai, A., (1991), "Entropy-based Criteria for Iintelligent Autonomous Systems", Proc. IEEE Intl' Symp. Intelligent Control 1991, Arlington VA., August 1991, pp. 55-60.

[4] Shannon, C., and Weaver, W., (1963), "The Mathematical Theory of Communications, Illini Books, 1963.

[5] Saridis G. N. (1995), "Stochastic Processes, Estimation and Control - The Entropy Approach", Wiley-Interscience, New-York, NY, 1995.

[6] Conant, R.C., (1976), "Laws of Information which Govern Systems", IEEE Trans. Systems, Man, Cybernetics, Vol. SMC-6, No. 4, 1976, pp. 240-255.

[7] Repperger, D.W., "An Autonomous Metric for Relative Comparisons of MIQ", Proceedings of the 2001 PerMIS Workshop, NIST, Gaithersburg, MD, September 2001, pp. 49-55.

[8] Clough, B.T., (2002), "Metrics, Schmetrics! How do you Track A UAV's Autonomy?", CD Proc. AIAA 1st Conference on Unmanned Air Systems, Portsmouth, VA., USA, May 2002, AIAA Paper # 2002-3499.

[9] Clough, B.T., (2002), Metrics, Schmetrics! How The Heck Do You Determine A UAV's Autonomy Anyway? CD Proc. of the 2002 PerMis Workshop, NIST, Gaithersburg, MD, August 2002, pp. 1-7.

[10] Rosenwasser, E., Yusupov, R., (2000), "Sensitivity of Automatic Control Systems", CRC Press, U.S.A., 2000.

[11] Yavnai, A., (2003), "Is System Autonomy a Quantifiable Attribute ? An Information-Based Approach for System Autonomy Metrics, Part I: Metrics Definition", CD Proceedings, 43rd Israel Annual Conference on Aerospace Sciences, Tel-Aviv, Israel, February,19-20 , 2003.

[12] Yavnai, A., (2003) "The Process of UCAV Autonomy Level Selection"' in CD-ROM Proceedings of Unmanned Systems '2003 Symposium, 15-17 July 2003, Baltimore, Maryland, USA, pp. xxxx.

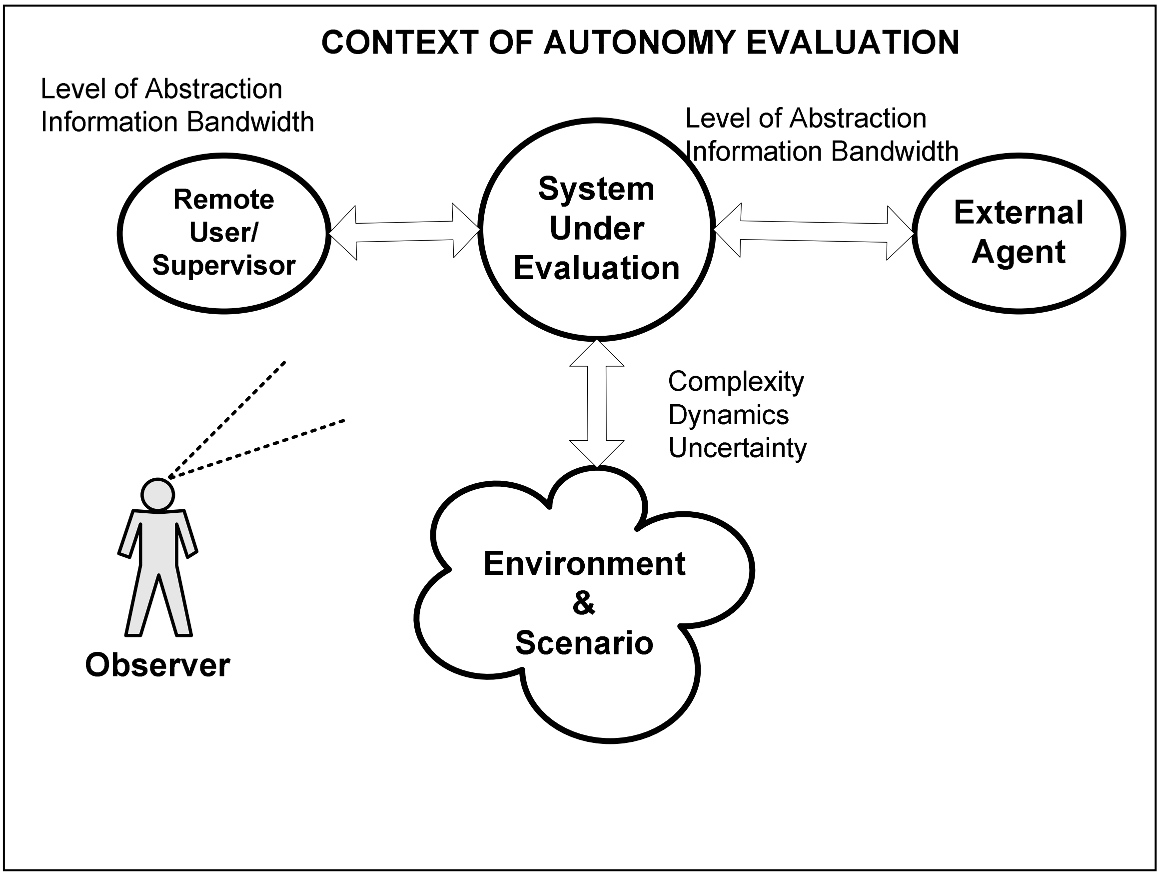

Fig. 1 The context of Autonomy Evaluation